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Character Association and Path Analysis for Yield and Yield Attributing Traits in Bread Wheat [*Triticum aestivum* (L.) em Thell] Genotypes

Harshlata Regar [a*], Abhay Dashora [a], Parul Gupta [a], Aliza Mariyam [a] and Avadhoot B. Dharmadhikari [a]

[a] Department of Genetics and Plant Breeding, Maharana Pratap University of Agriculture and Technology, Udaipur- 313001, Rajasthan, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The current study was conducted in *Rabi* 2021- 2022 at Instructional Farm, Rajasthan College of Agriculture, MPUAT, Udaipur to estimate the association among yield components and their direct and indirect influence on grain yield of bread wheat. For the overall traits under investigation, significant genotypic differences were found indicating the presence of huge amount of variation among studied genotypes. At both the genotypic and phenotypic levels, there was positive and significant correlation between grain yield and days to 50% heading, plant height, length of main spike, number of spikelet's per spike, number of grains per spike, grain weight per spike and biological yield per plant. Plant height had the greatest positive direct impact on grain production per plant followed by biological yield per plant, number of grains per spike, days to maturity and 1000-grain weight. It is, therefore, feasible to increase the grain yield per plant in bread wheat by taking into account certain traits *viz.*, plant height, biological yield per plant, number of grains per spike.

**Corresponding author: E-mail: regarharshlata@gmail.com;*

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1. INTRODUCTION

Bread wheat (*Triticum aestivum* (L.) em Thell), an annual plant of family *Poaceae,* is the most significant staple foods and the most popular cereal among the major cereals in the world. It serve as a crucial food source for most of the population of the world and provide around 20 % of the daily energy requirement Narwal et al. [1]. It is an angiosperm that is monocotyledonous and was developed in South West Asia. It stands second next to rice in production among cultivated crops and has been considered as "versatile cereal". "Wheat starch is one of the most important components in wheat grain and is extensively used as the main source in bread, noodles, and cookies. In addition to being a major source of starch and energy, it is good source of notably protein, vitamins (notably B vitamins), dietary fiber, and phytochemicals" Liu [2], Regvar et al. [3]; Lafiandra et al. [4]. "Wheat contains nearly 70% carbohydrate, 12% protein, 1.7% fat, 2.7% minerals, 2% dietary fiber, 12% moisture and considerable proportions of vitamins" Gillies et al. [5]. "The wheat grain contains 2-3% germ, 13-17% bran (outer layers of wheat grain) and 80-85% mealy endosperm (on a dry matter basis)" Belderok et al. [6]. "It is grown on 31.82 million hectares in India, with a production of 112.74 million tones and productivity of 3543 kg/ha" [7]. "The demand for wheat is rising and it is expected that by 2050, the requirement of wheat would be 60% higher than the present year" [8]. Therefore, in the 21st century, meeting the food demand of a growing population necessitates significant enhancements in crop production and productivity [9].

"Knowledge of the existing variation and the extent of association among yield contributing characters are essential for the development of high yielding cultivars. Correlation studies merely quantify the relationship between yield and its related attributes without providing the extent of yield dependence on the correlated factors. Path coefficient analysis measures the direct effect of a predictor variable upon its response variable and the second component being the indirect effect(s) of a predictor variable" [10].To increase the yield, study of direct and indirect effects of yield components provides the basis for its successful breeding programme and hence the problem of yield increase can be more effectively tackled on the basis of performance of yield components and selection for closely related characters. So, the objective of this investigation was to study the inter-relationships, and direct and indirect effects of yield and yield attributing traits in the bread wheat genotypes.

2. MATERIALS AND METHODS

40 bread wheat genotypes from the AICRP on Wheat and Barley, Department of Genetics and Plant Breeding were tested at Instructional Farm, Rajasthan College of Agriculture, MPUAT, Udaipur during *Rabi* 2021-22. All the 40 bread wheat genotypes were grown in Randomized Block Design with 3 replications. Genotypes were sown in 3 rows of 5m each in each replication, with a 20 cm between rows and a 5 cm between plants, *respectively*. All the recommended package of practices were followed to raise a good and healthy crop. Five competitive plants from each genotype were selected at random to record observations for 13 traits that were being studied including plant height (cm), number of effective tillers per plant, length of main spike (cm), number of spikelets per spike, number of grains per spike (g), grain weight per spike (g), 1000-grain weight (g), biological yield per plant (g), grain yield per plant (g), harvest index (%) and protein content (%). The data on days to 50 percent heading and days to maturity were recorded on the whole plot basis.

2.1 Statistical Data Analysis

2.1.1 Correlation studies

The analysis of variance was worked out as per the method suggested by Panse and Sukhatme [11]. Genotypic and phenotypic correlation coefficient was computed as per the formula suggested by Al- Jibouri et al. [12].

2.1.2 Genotypic correlation coefficient (r_g)

$$r_{xy}\,(g) = \frac{\text{Cov.xy (g)}}{\sqrt{\text{Vx (g).Vy (g)}}}$$

2.1.3 Phenotypic correlation coefficient (r_p)

$$r_{xy}\,(p) = \frac{\text{Cov.xy (p)}}{\sqrt{\text{Vx (p).Vy (p)}}}$$

Where,

R_{xy} (g) = Genotypic correlation coefficient between x and y characters

R_{xy} (p) = Phenotypic correlation coefficient between x and y characters
V_x (g) = Genotypic variance of x character
V_y (g) = Genotypic variance of y character
V_x (p) = Phenotypic variance of x character
V_y (p) = Phenotypic variance of y character
Cov_{xy} (g) = Genotypic covariance of x and y characters
Cov_{xy} (p) = Phenotypic covariance of x and y characters

2.1.4 Test of Significance

The significance of correlation coefficient was tested by the 't' test given by W. S. Gosset [13].

2.2 Path Coefficient Analysis

The path coefficient was calculated by using the method of Dewey and Lu [10].

2.2.1 Direct effect

$r_{(x1,y)} = P_{1y} + r_{(x1,x2)}P_{2y} + r_{(x1,x3)}P_{3y} + \ldots\ldots\ldots\ldots r_{(x1,x13)}P_{13y}$ $r_{(x1,y)}$
Correlation coefficient between x_1 and y
P_{1y} = Direct effect of x_1 on y
$R_{(x1,x2)}P_{2y}$ = Indirect effect of x_1 on y *via* x_2
$r_{(x1,x13)}P_{13y}$ = Indirect effect of x_1 on y *via* x_{13}

Similar procedure used for r (x_2, y) to r (x_{13}, y).

2.2.2 Residual effect

$$R = \sqrt{1 - \left(\sum P_{iy} - r_{iy}\right)}$$

Where,

R = Residual effect
P_{iy} = Direct effect of x_i on y
r_{iy} = Correlation coefficient between x_i and y

3. RESULTS AND DISCUSSION

The analysis of variance has unveiled noteworthy distinctions among the genotypes for the majority of the studied traits, signifying a significant level of variability in the materials. This substantiates the rationale behind selecting these experimental materials (Table 1).

3.1 Correlation Coefficient Analysis

The present investigation revealed that grain yield per plant had positive and significant correlation with days to 50 percent heading, plant height, length of main spike, number of spikelets per spike, number of grains per spike, grain weight per spike and biological yield per plant at both genotypic (Table 2) and phenotypic levels (Table 3) while it showed positive and significant correlation with harvest index at genotypic level only (Table 2). Similar results were also reported by Sharma et al. [14]; Santhoshini et al. [15]; Zu et al. [16]; Baye et al. [17]; Nagar et al. [18]. Days to maturity shows negative and significant correlation with harvest index while biological yield per plant shows negative and significant correlation with harvest index and protein content at both genotypic (Table 2) and phenotypic levels (Table 3). While correlation analysis offers valuable insights, it is limited in that it does not shed light on the underlying causal factors driving the various inter-relationships. However, by conducting an analysis of path coefficients, we can gain a more comprehensive understanding of the causal basis behind these inter-relationships Nukasani et al. [19].

Table 1. Analysis of variance for yield and its contributing traits in bread wheat

S.NO	Characters	Replication	Genotype	Error
		[2]	[39]	[78]
1.	Days to 50 percent heading	0.41	21.23**	2.79
2.	Days to maturity	0.91	27.28**	3.67
3.	Plant height (cm)	44.78	136.15**	28.45
4.	Number of effective tillers per plant	0.93	1.19**	0.40
5.	Length of main spike (cm)	0.93	2.98**	0.57
6.	Number of spikelets per spike	0.93	6.72**	1.04
7.	Number of grains per spike	35.21	376.65**	13.04
8.	Grain weight per spike (g)	0.66	0.89**	0.24
9.	1000-grain weight (g)	1.61	60.88**	3.20
10.	Biological yield per plant (g)	4.36	95.26**	9.55
11.	Grain yield per plant (g)	4.61	16.31**	2.78
12.	Harvest index (%)	15.56	34.83**	8.57
13.	Protein content (%)	0.51	6.67**	0.27

**, ** Significant at 5% and 1% respectively*

Table 2. Genotypic (rg) correlation coefficient for different characters in bread wheat

Character	Days to 50% heading	Days to maturity	Plant height	Number of effective tillers per plant	Length of main spike	Number of spikelets per spike	Number of grains per spike	Grain weight per spike	1000-grain weight	Biological yield per plant	Harvest index	Protein content	Grain yield per plant
Days to 50% heading		0.48**	0.56**	0.21	0.36*	0.16	0.28	0.25	0.03	0.43*	-0.12	-0.35*	0.39*
Days to maturity			-0.14	0.32	-0.01	0.06	0.00	-0.11	0.11	0.02	-0.37*	-0.11	-0.20
Plant height				-0.19	0.74**	0.63**	0.57*	0.67**	0.21	0.52**	0.31	0.06	0.73**
Number of effective tillers per plant					-0.44**	-0.32	-0.30	-0.30	-0.15	0.01	-0.19	-0.10	-0.06
Length of main spike						0.74**	0.78**	0.99**	0.41*	0.63**	-0.20	-0.01	0.51**
Number of spikelets per spike							0.77**	0.79**	0.22	0.49**	0.01	0.02	0.50**
Number of grains per spike								1.01**	0.17	0.57**	0.02	-0.15	0.60**
Grain weight per spike									0.46**	0.64**	-0.03	-0.06	0.63**
1000- grain weight										0.20	-0.09	0.09	0.17
Biological yield per plant											-0.37*	-0.35*	0.81**
Harvest index												0.15	0.41**
Protein content													-0.22
Grain yield per plant													

*, ** significant at 5% and 1% respectively, here 0.00 values indicate negligible correlation

Table 3. Phenotypic (rp) correlation coefficient for different characters in bread wheat

Character	Days to 50% heading	Days to maturity	Plant height	Number of effective tillers per plant	Length of main spike	Number of spikelets per spike	Number of grains per spike	Grain weight per spike	1000-grain weight	Biological yield per plant	Harvest index	Protein content	Grain yield per plant
Days to 50% heading		0.38**	0.31**	0.08	0.27*	0.19	0.24	0.13	0.03	0.35**	-0.03	-0.28*	0.32**
Days to maturity			-0.10	0.10	0.05	0.05	0.02	0.00	0.08	0.06	-0.25*	-0.07	-0.12
Plant height				0.02	0.54**	0.42**	0.43*	0.30**	0.13	0.37**	0.19	0.06	0.49**
Number of effective tillers per plant					-0.23*	-0.14	-0.23	-0.19	-0.09	0.02	-0.05	-0.01	-0.01
Length of main spike						0.49**	0.60**	0.56**	0.28	0.46**	-0.06	0.01	0.37**
Number of spikelets per spike							0.63**	0.49**	0.14	0.38**	-0.01	0.02	0.34**
Number of grains per spike								0.66**	0.15	0.49**	0.02	-0.13	0.46**
Grain weight per spike									0.27*	0.42**	-0.07	-0.08	0.34**
1000- grain weight										0.19	-0.08	0.08	0.14
Biological yield per plant											-0.29*	-0.26	0.75**
Harvest index												0.05	0.26
Protein content													-0.26
Grain yield per plant													

**, ** significant at 5% and 1% respectively*

Table 4. Estimate of direct effect (diagonal) and indirect effect (off diagonal) at genotypic level for grain yield per plant in bread wheat

S. No.	Character	Days to 50% Heading	Days to maturity	Plant height	Number of effective tillers per plant	Length of main spike	Number of spikelets per spike	Number of grains per spike	Grain weight per spike	1000-grain weight	Biological yield per plant	Protein content	r with grain yield per plant
1	Days to 50% heading	-0.523	0.0889	0.6635	-0.0244	-0.2811	-0.0574	0.1936	-0.064	0.0044	0.3234	0.0646	0.3885*
2	Days to maturity	-0.2531	0.1837	-0.1626	-0.037	0.0067	-0.0213	-0.0026	0.0286	0.0166	0.0175	0.0211	-0.2023
3	Plant height	-0.2908	-0.025	1.1934	0.0212	-0.571	-0.2271	0.3943	-0.1731	0.0323	0.3901	-0.0116	0.7328**
4	Number of effective tillers per plant	-0.1119	0.0595	-0.2221	-0.1142	0.343	0.1145	-0.2101	0.078	-0.0219	0.0085	0.0181	-0.0586
5	Length of main spike	-0.1894	-0.0016	0.8781	0.0504	-0.7761	-0.268	0.5372	-0.2546	0.0614	0.4713	0.0025	0.5112**
6	Number of spikelets per spike	-0.0828	0.0108	0.7478	0.0361	-0.5738	-0.3624	0.53	-0.203	0.0338	0.369	-0.0029	0.5024**
7	Number of grains per spike	-0.1468	-0.0007	0.6821	0.0348	-0.6042	-0.2784	0.6899	-0.2606	0.026	0.428	0.0268	0.597**
8	Grain weight per spike	-0.1296	-0.0204	0.799	0.0344	-0.7646	-0.2846	0.6956	-0.2585	0.0693	0.4792	0.0103	0.6302**
9	1000-grain weight	-0.0151	0.0202	0.2548	0.0166	-0.3155	-0.081	0.1189	-0.1186	0.1511	0.1524	-0.0159	0.1679
10	Biological yield per plant	-0.2254	0.0043	0.6206	-0.0013	-0.4875	-0.1782	0.3936	-0.1651	0.0307	0.7503	0.0638	0.8056**
11	Protein content	0.1834	-0.0211	0.0753	0.0112	0.0107	-0.0057	-0.1006	0.0144	0.013	-0.2597	-0.1842	-0.2632

R= 0.1037

**, ** Significant correlation with dependent character at 5% and 1% respectively*

3.2 Path Coefficient Analysis

3.2.1 Direct and indirect effects

The findings from the current investigation on path coefficient analysis are showcased in Table 4. The results indicate that several factors, plant height, biological yield per plant, number of grains per spike, days to maturity and 1000-grain weight had positive direct effect on grain yield. Similar findings reported by Sharma et al. [14]; Santhoshini et al. [15]; Singh et al. [20]. Consequently, focusing and selecting these specific traits would prove beneficial in effectively enhancing the overall productivity of bread wheat. However, traits like length of main spike, days to 50 percent heading, number of spikelets per spike, grain weight per spike, protein content and number of effective tillers per plant exhibited negative direct effect on grain yield per plant. Since the direct effect were negative, so the direct selection for these traits to improve yield will be undesirable. Similar results were in accordance with findings of Singh et al. [20]; Zu et al. [16]; Kumar et al. [21]; Ayer et al. [22]; Nagar et al. [18]. Number of grains per spike showed positive indirect effect *via* plant height, biological yield per plant.

3.2.2 Residual effect

Residual effect in the present study was computed (R= 0.1037) showing that 89.63 % of the variability in grain yield was demonstrated by the traits considered for path study. It also indicates that in addition to the studied characters, there are also other factors to justify grain yield per plant Abd El-Mohsen et al. [23].

4. CONCLUSION

Based on the aforementioned findings, it may be concluded that Plant height, number of grains per spike, biological yield per plant exerted positive direct effect along with positive and significant correlation on grain yield per plant. These characters must be given preference in selection while selecting the superior genotypes. Therefore, these particular traits should be considered for enhancing yields in the wheat breeding program.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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